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(54) **IGNITER CIRCUIT FOR AN HID LAMP**

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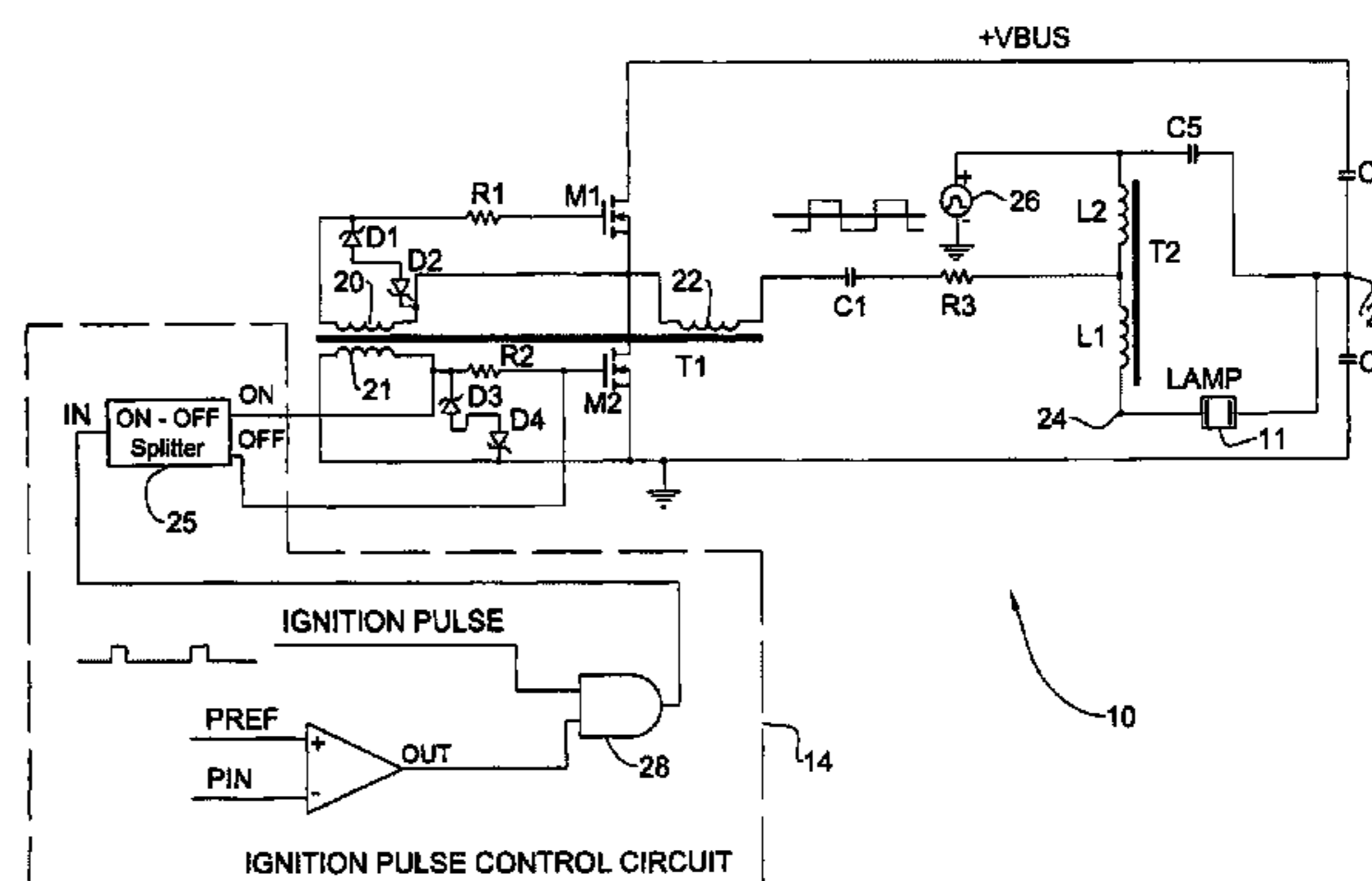
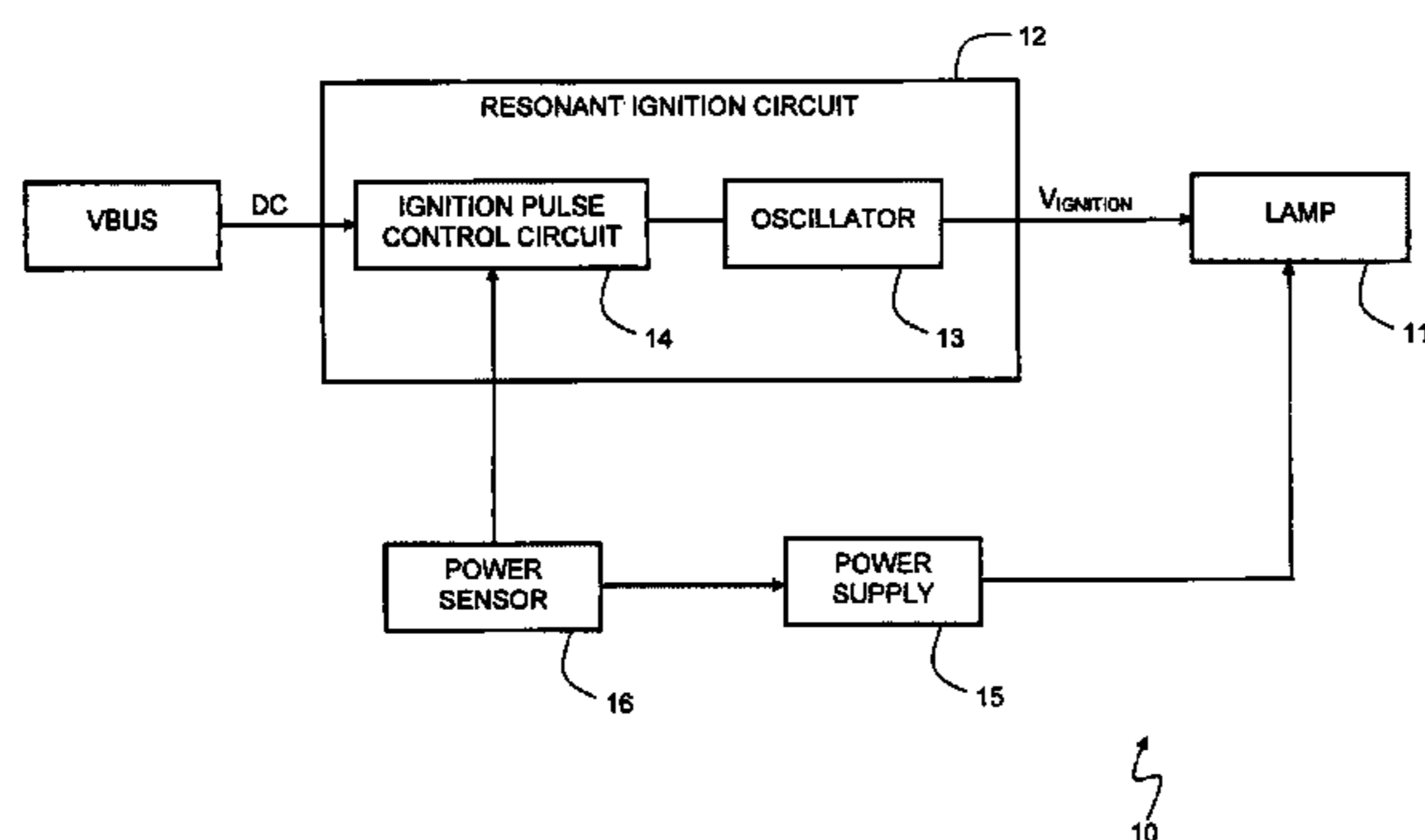
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(57) **ABSTRACT**

An igniter circuit (10) for an HID lamp (11) has a DC input (VBUS) for coupling to a source of DC voltage, and an output (23, 24) for coupling to the HID lamp. A resonant ignition circuit (12) operating at a controlled resonant frequency is coupled to the DC input for producing successive bursts of voltage having a frequency equal to the resonant frequency and having an amplitude that increases with time. The resonant ignition circuit (12) feeds the bursts of voltage across the output of the igniter until an HID lamp coupled thereto reaches breakdown.

16 Claims, 3 Drawing Sheets



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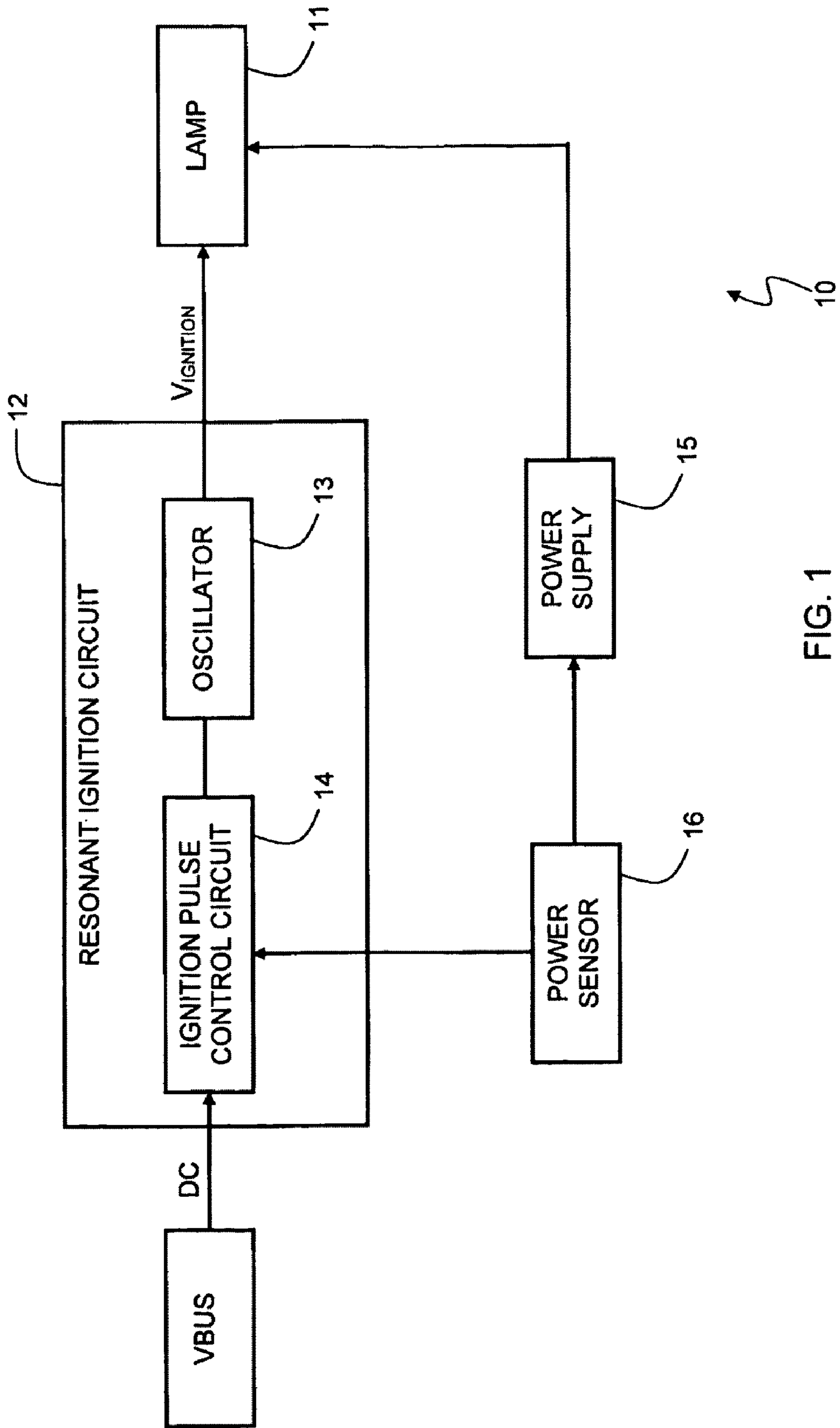


FIG. 1

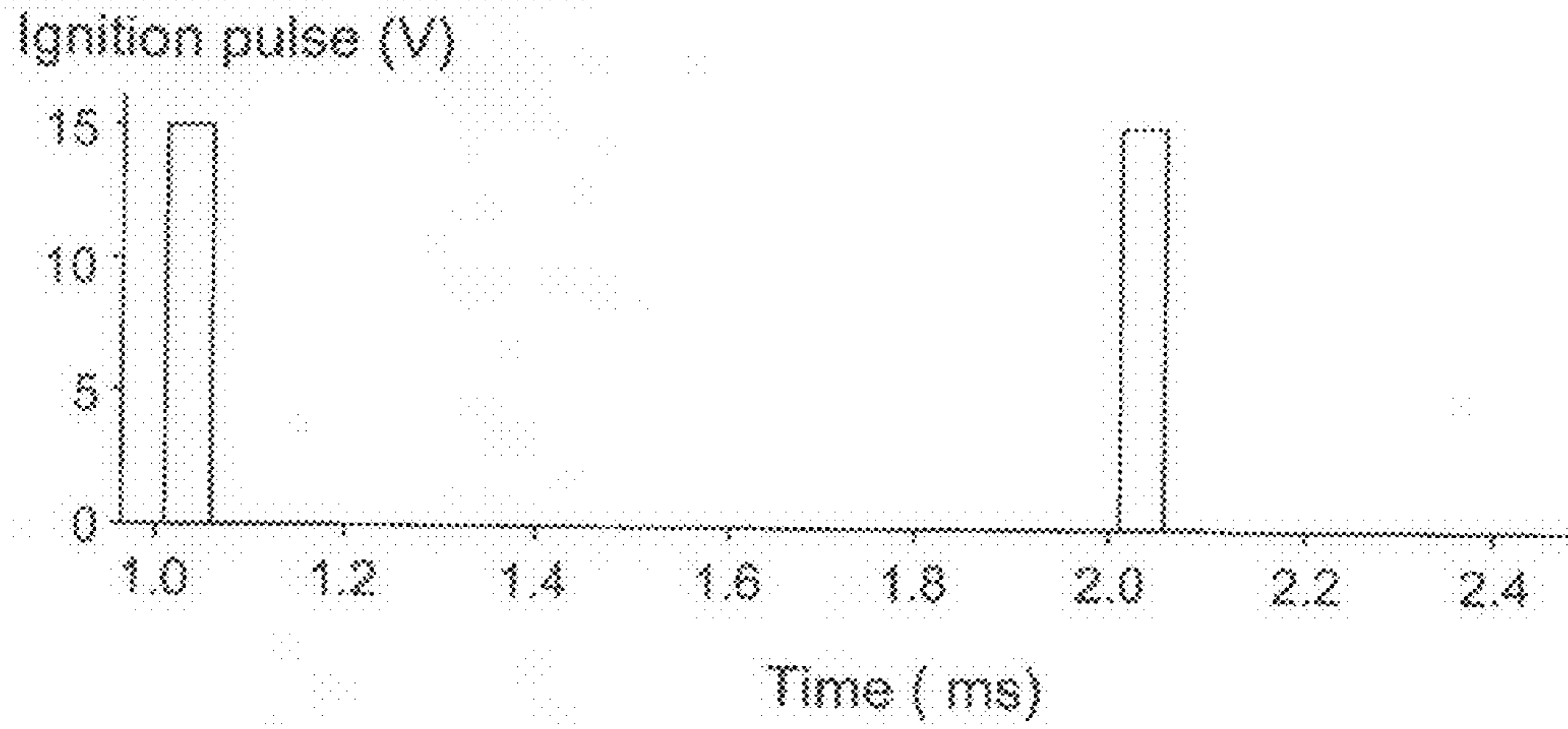


FIG. 3

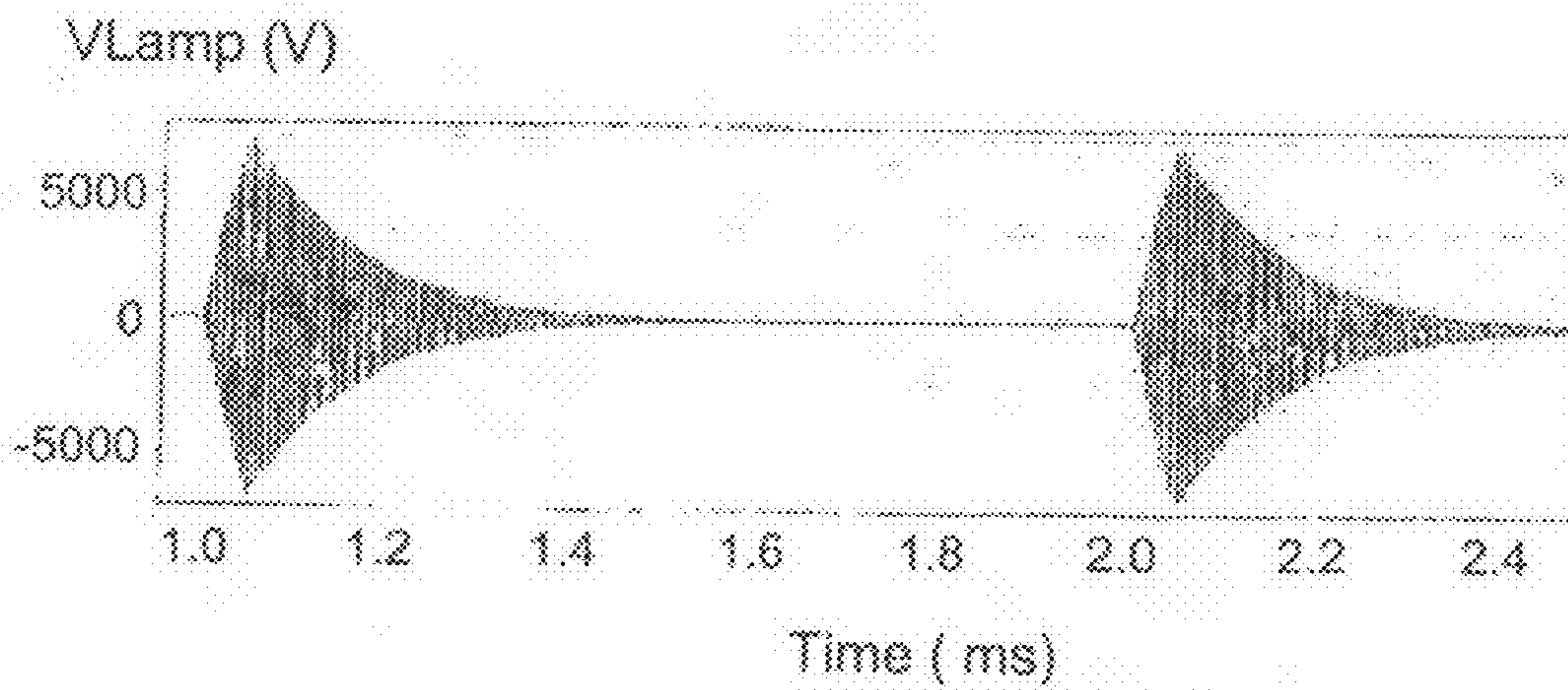


FIG. 4

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IGNITER CIRCUIT FOR AN HID LAMP

FIELD OF THE INVENTION

This invention relates to igniters for high intensity discharge lamps.

BACKGROUND OF THE INVENTION

The function of a high-intensity discharge (HID) electronic ballast is to supply ignition to the lamp for starting and then operating the lamp, such as a metal halide lamp. A metal halide lamp is a gas discharge lamp in which metal halides are enclosed, for example, in a quartz envelope.

To initiate its operation, a metal halide lamp demands a high ignition voltage. Once the lamp is ignited, the voltage falls to low voltage of the order of 20 V and the lamp is then maintained for a short time (typically between 1-2 minutes) in so-called "current mode" where the current is constant and the voltage rises until the lamp reaches nominal power, whereafter the ballast serves to stabilize the power.

Prior art igniter circuits are known where an uncontrolled oscillator frequency is swept from a frequency that is less than the resonant frequency such that when it reaches resonance the voltage reaches maximum value and the lamp strikes. However, during this operation the frequency continues to rise and the voltage therefore falls.

SUMMARY OF THE INVENTION

It is an object of the invention to provide an igniter circuit for an HID lamp that employs a self-oscillating power supply for applying across the lamp a high ignition voltage that increases with time.

It is a further object to provide such an igniter circuit that is configured for coupling directly to an inverter having a half bridge topology for feeding low frequency current to the lamp after ignition.

These objects are realized in accordance with a first aspect of the invention by an igniter circuit for an HID lamp, the igniter circuit comprising:

- a DC input for coupling to a source of DC voltage,
- an output for coupling to the HID lamp, and
- a resonant ignition circuit operating at a controlled resonant frequency coupled to said DC input for producing successive bursts of voltage having a frequency equal to the resonant frequency and having an amplitude that increases with time and for feeding said bursts of voltage across the output of the igniter until an HID lamp coupled thereto reaches breakdown.

According to a second aspect of the invention, there is provided a method for igniting a HID lamp, the method comprising:

- using a resonant circuit connected across the lamp to generate successive bursts of voltage having a frequency equal to the resonant frequency and having an amplitude that increases with time; and

- applying said bursts of voltage across the HID lamp until the lamp ignites, thereby loading the resonant circuit so that its Q factor falls sufficiently to stop the resonant circuit resonating.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to understand the invention and to see how it may be carried out in practice, a preferred embodiment will now be

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described, by way of non-limiting example only, with reference to the accompanying drawings, in which:

FIG. 1 is a block diagram showing the functionality of an igniter circuit for an HID lamp in accordance with an exemplary embodiment of the invention;

FIG. 2 is a schematic circuit diagram of the igniter circuit shown functionally in FIG. 1;

FIG. 3 is a waveform showing graphically a series of ignition pulses fed to the with the igniter circuit shown in FIG. 2; and

FIG. 4 is a waveform showing graphically a resonant frequency voltage whose amplitude increases with time and that is applied to the HID lamp prior to ignition.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

FIG. 1 is a block diagram showing the functionality of an igniter circuit **10** according to the invention for an HID lamp **11**. The igniter circuit **10** is operated from a DC power source, VBUS, which is not itself part of the igniter circuit **10** and may be generated in manner well known to those skilled in the art. The DC power source, VBUS, is fed to a controlled self-oscillator **12** comprising a self oscillator **13** controlled by an ignition pulse control circuit **14**. The HID lamp **11** is coupled to the controlled self-oscillator **12** which constitutes an igniter circuit for igniting the lamp. The lamp is powered by a power supply **15**, which conveniently is coupled to the DC power source, VBUS, although it could be independent thereof. In order to disable operation of the igniter circuit after ignition of the HID lamp **11**, a power sensor **16** is responsively coupled to the DC power source, VBUS, so as to sense the current supplied thereby. Before the lamp **11** ignites the current sensed by the power sensor **16** is low; but once the lamp **11** ignites it draws power from the DC power source, VBUS. The power sensor **16** thus serves to indicate whether or not the HID lamp **11** has ignited. The ignition pulse control circuit **14** is responsively coupled to the power sensor **16** so as to cease operation when the power sensor **16** senses that the HID lamp **11** has ignited. For the sake of completeness, although not relevant to the igniter circuit per se, the power sensor **16** serves a second function in that the power supply **15** includes a power regulator (not shown) that is responsive to the power sensed by the power sensor **16** for stabilizing the nominal power to the lamp **11**.

FIG. 2 is a schematic circuit diagram showing in detail a preferred embodiment of the igniter circuit **10** shown in FIG. 1.

Resonant Ignition Circuit

The oscillator **13** comprises a drive transformer T1 having first, second and third windings **20**, **21** and **22**, respectively, which are connected in the correct polarity for positive feedback (oscillation). A first end of the first winding **20** is coupled to the source terminal of a first MOSFET M1 whose gate terminal is coupled via a resistor R1 to a second end of the first winding **20**. The drain terminal of the first MOSFET M1 is coupled to VBUS, typically having a voltage of 400 VDC. A pair of zener diodes D1 and D2 is coupled back to back across the first winding **20**, their anodes being commonly connected and their respective cathodes being connected to opposite ends of the first winding **20**. The zener diodes D1, D2, limit the gate voltage fed to the MOSFET M1 and thereby ensure that when the resonant voltage increases, it does not damage the gate of the MOSFET M1.

In complementary trimmer, the first end of the second winding 21 is coupled via a resistor R2 to the gate terminal of a second MOSFET M2 whose source terminal is coupled to a second end of the second winding 21 and constitutes the ground rail, GND. The drain terminal of the second MOSFET M2 is coupled to the source terminal of the first MOSFET M1. A pair of zener diodes D3 and D4 is coupled back to back across the first winding 20, their anodes being commonly connected and their respective cathodes being connected to opposite ends of the second winding 21. The zener diodes D3 and D4 limit the gate voltage fed to the MOSFET M2 and thereby ensure that when the resonant voltage increases, it does not damage the gate of the MOSFET M2. The first end of the second winding 21 is coupled to an 'ON' control output of an ON-OFF splitter 25, its second end being coupled to GND. An 'OFF' control output of the ON-OFF splitter 25 is connected to the gate of the MOSFET M2. An input of the ON-OFF splitter 25 is connected to an output of the ignition pulse control circuit 14, as will be described in more detail below. The ON-OFF splitter 25 serves to convey an ignition pulse conveyed by the ignition pulse control circuit 14 to the winding 21 of the drive transformer T1 to enable the oscillation process; and to convey a disable signal to the gate of the MOSFET M2 to prevent oscillation after the lamp 11 has ignited.

A first end of the third winding 22 of the oscillator drive transformer T1 is connected to a first capacitor C1 connected in series with a first end of a resistor R3, whose second end is coupled to the common junction of a split winding of a transformer T2, comprising windings L1, L2. The coils L1 and L2 are wound such that a first end of the coil L1 is connected to a second end 23 of the coil L2, whose first end is connected to a first end of the HID lamp 11. A second end of the third winding 22 is connected to the common junction of the two MOSFETs M1 and M2, i.e. to the source of M1 and to the drain of M2.

The DC power source, VBUS, comprises pair of large series connected electrolytic capacitors C2 and C4 connected between VBUS and GND, their common junction 24 being connected to a second end of the HID lamp 11 and to the second end of the coil L1 via a capacitor C5. The capacitors C2 and C4 serve as storage capacitors for storing DC voltage for powering the controlled self-oscillator 12 and the power supply 15. The power supply 15 operates as a low frequency square wave current source controlled power shown as 26 in FIG. 2 that is connected to the common junction of the coil L1 and the capacitor C5. The low frequency square wave current source is produced in known manner by an inverter (not shown). Preferably, the inverter is a half-bridge topology of which the capacitors C2 and C4 are integral components. The junction of the capacitors C2 and C4 and the first end of the coil L2 constitute output terminals of the igniter circuit 10 across which the HID lamp 11 is coupled.

Having described the topology of the resonant ignition circuit 12, its operation will now be described.

The resonant ignition circuit is constituted by M1 and M2, R1, R2, D1, D2, D3, D4, T1, C1, R3, L1, C4 (short), C5 (short) and its resonant frequency f_0 is determined by C1, L1 in accordance with the equation:

$$f_0 = \frac{1}{2\pi\sqrt{L1 \cdot C1}}$$

C4 and C5 have very low impedance at the resonant frequency and so practically behave as short circuits. The Q

factor is determined by the values of R1, R2, R3. The resistors R1 and R2 together with the input capacitances of the gates of the two MOSFETs M1 and M2 create a phase shift which causes a reduction in the resonant voltage fed to the lamp.

The Q factor determines the maximum peak voltage that may be fed to the HID lamp 11 before breakdown, which may be several kilovolts, whereafter the voltage fed to the lamp falls to a low voltage, typically in the order of 20V and is maintained at constant current until it reaches the nominal power of the lamp.

A train of ignition pulses shown graphically in FIG. 3 at the resonant frequency f_0 is fed to the junction between the source of M1 and the drain of M2 through the resonant circuit constituted by C1 and L1, so that the resonant circuit resonates with increasing amplitude for the duration of each ignition pulse as shown graphically in FIG. 4 due to the positive feedback produced by the windings of the drive transformer, T1. At the end of each ignition pulse, the amplitude of the resonant lamp voltage decreases until it reaches substantially zero until the arrival of the next ignition pulse, when the cycle is repeated. As noted, C4 has low impedance at the resonant frequency and acts as a short circuit.

When the lamp 11 starts to conduct, the lamp acts as a low impedance, and the current through the lamp fed by the low frequency current source 26 (corresponding to the power supply 15 shown in FIG. 1) flows through L1 and L2 which together operate as a choke, which filters some of the high frequency ripple. C5 acts as a first filter for removing the high frequency ripple superimposed on the low frequency current. C2 and C4 whose mid-point voltage is equal to half VBUS form part of a half bridge inverter that serves to supply low frequency current to the lamp 11 after ignition; and are thus integral components of the power supply shown as 15 in FIG. 1 and of the low frequency current source shown as 26 in FIG. 2.

Before lamp breakdown, the transformer T2 serves as the lamp igniter; and after breakdown when the lamp starts to conduct in the current mode, it serves as a choke for removing the high frequency ripple.

The object is to generate a high voltage waveform with increasing amplitude that is applied to the lamp as shown graphically in FIG. 4. When the lamp voltage reaches a certain voltage (1 kV-4 kV depending on lamp temperature), the lamp ignites. When this happens, the lamp impedance falls to a low value and loads the resonant circuit so that its Q factor falls significantly and it stops resonating. The self-oscillation circuit stops the oscillator coil T1 from oscillating.

Ignition Pulse Control Circuit

As noted above, the oscillator 13 stops oscillating when the HID lamp 11 ignites owing to the fact that the low lamp impedance after ignition loads the resonant circuit causing a marked reduction in its Q factor. However, rather than rely on this alone, it is considered preferable to disable the ignition circuit once the lamp has ignited, this being achieved by the igniter pulse control circuit 14. The igniter pulse control circuit 14 comprises a comparator 27 having a positive input to which a reference voltage signal PREF is fed and having a negative input coupled to the power sensor 16 so as to receive a voltage signal PIN that is proportional to the power across the HID lamp 11. Ignition pulses shown graphically in FIG. 3 having a duty cycle determined by T_{ON} and T_{OFF} are fed to one input of a 2-input AND-gate 28 while the logic signal at the output of the comparator is fed to the second input of the AND-gate 28. Before the lamp starts conducting, PIN is low and the comparator output is logic HIGH; the AND-gate 28

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therefore conveys the ignition pulses to the ON-OFF splitter 25. When the lamp ignites, PIN is larger than PREF and the output of the comparator 27 goes to LOW, whereupon the AND-gate 28 stops feeding the ignition pulses to the ON-OFF splitter 25.

The oscillator 13 is self-controlled to operate at the resonant frequency as determined by C1 and L1 such that although differences in the values of C1 and L1, as may occur in mass production owing to component tolerances will give rise to different resonant frequencies, the oscillator 13 will always operate at resonant frequency.

Moreover, the resonant frequency at which the oscillator 13 resonates is also a function of the parasitic capacitance of the wires connecting the HID lamp 11 to the resonant ignition circuit 12, being a function of their length. Therefore, the oscillator 13 resonates at resonant frequency regardless of the length of the wires connecting the HID lamp 11 to the resonant ignition circuit 12.

The invention claimed is:

1. An igniter circuit for an HID lamp, the igniter circuit comprising:

a DC input for coupling to a source of DC voltage,

an output for coupling to the HID lamp,

a resonant ignition circuit including:

an oscillator operating at a self-oscillating resonant frequency coupled to said DC input for producing successive bursts of voltage having a frequency equal to the resonant frequency and having an amplitude that increases with time and for feeding said bursts of voltage across the output of the igniter until an HID lamp coupled thereto reaches breakdown, so as to cause the lamp impedance to fall to a low value and load the resonant circuit so that its Q factor falls significantly and stops resonating thereby stopping the oscillator from oscillating;

a current source having a low frequency component and high frequency component;

a transformer comprising a first coil and a second coil connected in series with each other, the second coil being connected in series with the lamp, the first coil being part of the oscillator prior to ignition and, after ignition, serving to block the high frequency component so as to pass the low frequency component to the lamp; and

a first capacitor having a first end coupled to the first coil and having a second end coupled to both the lamp and to a first end of a second capacitor having a second end connected to ground (GND), said first capacitor and second capacitor being configured for passing the high frequency component from the current source to GND.

2. The igniter circuit according to claim 1, wherein the input includes a pair of storage capacitors that are adapted to store high voltage DC, one of said storage capacitors being constituted by the second capacitor.

3. The igniter circuit according to claim 2, wherein the pair of storage capacitors serve to connect directly to respective outputs of a half-wave bridge rectifier.

4. The igniter circuit according to claim 3, wherein said storage capacitors are integral components of an inverter having a half-bridge topology.

5. The igniter circuit according to claims 1, wherein the ignition pulse control circuit is coupled to a sensor responsive to a function of power across the HID lamp for disabling the high voltage oscillator circuit upon ignition of the HID lamp.

6. The igniter circuit according to claim 1, wherein the oscillator comprises:

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a drive transformer having a first winding, a second winding and a third winding connected for producing positive feedback,

a first end of the first winding being coupled to the source terminal of a first MOSFET whose gate terminal is coupled via a resistor to a second end of the first winding,

the drain terminal of the first MOSFET being coupled to the DC input,

the first end of the second winding being coupled via a resistor to the gate terminal of a second MOSFET whose source terminal is coupled to a second end of the second winding and constitutes a ground rail,

the drain terminal of the second MOSFET being coupled to the source terminal of the first MOSFET,

the first end of the second winding being coupled to an ON control output of an ON-OFF splitter that is adapted to convey an ignition pulse conveyed by the ignition pulse control circuit to the second winding of the drive transformer to enable oscillation; and to convey a disable signal to the gate of the second MOSFET to prevent oscillation after the lamp has ignited,

a second end of the second winding being coupled to GND, an OFF control output of the ON-OFF splitter being connected to the gate of the second MOSFET,

an input of the ON-OFF splitter being connected to an output of the ignition pulse control circuit,

a first end of the third winding of the oscillator drive transformer being connected to a first capacitor connected in series with a first end of a resistor,

a second end of the resistor being coupled to a common junction of a split winding of a transformer comprising a first coil and a second coil wound such that a first end of the first coil is connected to a second end of the second coil,

a first end of the second coil being connected to a first end of the HID lamp, and

a second end of the third winding being connected to the source of the first MOSFET and to the drain of the second MOSFET.

7. The igniter circuit according to claim 6, wherein the oscillator further comprises:

a pair of zener diodes coupled back to back across the first winding, their anodes being commonly connected and their respective cathodes being connected to opposite ends of the first winding, and

a pair of zener diodes coupled back to back across the first winding, their anodes being commonly connected and their respective cathodes being connected to opposite ends of the second winding.

8. A method for igniting a HID lamp, the method comprising:

using a self-oscillating resonant circuit connected across the lamp to generate successive bursts of voltage having a frequency equal to the resonant frequency and having an amplitude that increases with time;

applying said bursts of voltage across the HID lamp until the lamp ignites, thereby loading the resonant circuit so that its Q factor falls sufficiently to stop the resonant circuit self-resonating;

providing a current source having a low frequency component and a high frequency component;

feeding the current source to the lamp through a transformer having a first coil and a second coil connected in series with each other and the second coil being connected in series with the lamp;

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prior to ignition, using the first coil as part of the oscillator for generating the resonant frequency; and after ignition, using the first coil as part of a choke for blocking the high frequency component so as to feed the low frequency component of the current source to the lamp for maintaining the lamp operative while filtering the high frequency component.

9. The method according to claim 8, further including substantially immediately disabling operation of the resonant circuit after lamp ignition.

10. An igniter circuit for an HID lamp, the igniter circuit comprising:

a DC input for coupling to a source of DC voltage,
 an output for coupling to the HID lamp,
 a resonant ignition circuit operating at a controlled resonant frequency coupled to said DC input for producing successive bursts of voltage having a frequency equal to the resonant frequency and having an amplitude that increases with time and for feeding said bursts of voltage across the output of the igniter until an HID lamp coupled thereto reaches breakdown;

wherein the resonant ignition circuit includes an oscillator controlled by an ignition pulse control circuit coupled thereto and the oscillator comprises:

a drive transformer having a first winding, a second winding and a third winding connected for producing positive feedback,

a first end of the first winding being coupled to the source terminal of a first MOSFET whose gate terminal is coupled via a resistor to a second end of the first winding,

the drain terminal of the first MOSFET being coupled to the DC input,

the first end of the second winding being coupled via a resistor to the gate terminal of a second MOSFET whose source terminal is coupled to a second end of the second winding and constitutes a ground rail,

the drain terminal of the second MOSFET being coupled to the source terminal of the first MOSFET,

the first end of the second winding being coupled to an ON control output of an ON-OFF splitter that is adapted to convey an ignition pulse conveyed by the ignition pulse control circuit to the second winding of the drive transformer to enable oscillation; and to convey a disable signal to the gate of the second MOSFET to prevent oscillation after the lamp has ignited,

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a second end of the second winding being coupled to GND,

an OFF control output of the ON-OFF splitter being connected to the gate of the second MOSFET,

an input of the ON-OFF splitter being connected to an output of the ignition pulse control circuit,

a first end of the third winding of the oscillator drive transformer being connected to a first capacitor connected in series with a first end of a resistor,

a second end of the resistor being coupled to a common junction of a split winding of a transformer comprising a first coil and a second coil wound such that a first end of the first coil is connected to a second end of the second coil,

a first end of the second coil being connected to a first end of the HID lamp, and

a second end of the third winding being connected to the source of the first MOSFET and to the drain of the second MOSFET.

11. The igniter circuit according to claim 10, wherein the oscillator further comprises:

a pair of zener diodes coupled back to back across the first winding, their anodes being commonly connected and their respective cathodes being connected to opposite ends of the first winding, and

a pair of zener diodes coupled back to back across the second winding, their anodes being commonly connected and their respective cathodes being connected to opposite ends of the second winding.

12. The igniter circuit according to claim 10, wherein the ignition pulse control circuit is coupled to a sensor responsive to a function of power across the HID lamp for disabling the high voltage oscillator circuit upon ignition of the HID lamp.

13. The igniter circuit according to claim 10, wherein the input includes a pair of storage capacitors that are adapted to store high voltage DC, one of said storage capacitors being constituted by the second capacitor.

14. The igniter circuit according to claim 13, wherein the pair of storage capacitors serve to connect directly to respective outputs of a half-wave bridge rectifier.

15. The igniter circuit according to claim 13, wherein said storage capacitors are integral components of an inverter having a half-bridge topology.

16. The igniter circuit according to claims 10, wherein the ignition pulse control circuit is coupled to a sensor responsive to a function of power across the HID lamp for disabling the high voltage oscillator circuit upon ignition of the HID lamp.

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